Institute of Transportation Studies
University of California, Davis

ITS-Davis Overview

Austrian Business Delegation

May 15, 2009

Environmental Transportation at UC Davis

ITS-Davis founded 1991

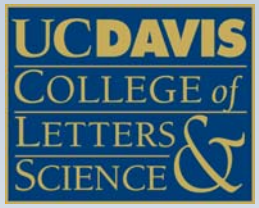
Today …

- 60 academic and research faculty
- New faculty – Rapson (Economics), Park, (Mechanical Engineering)
- 97 graduate students (winter 2009)
- Expanded role in policy-driving research

Summer Picnic

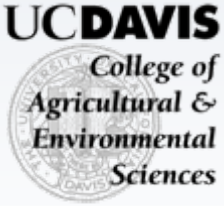
UC Davis Model
Transportation Research Structure

Chemical and Materials Science
Civil and Environmental
Mechanical



Anthropology
Chemistry
Economics
Statistics

Transportation Technology and Policy Degree



Ecology
Environmental Science and Policy

Board of Advisors

James D. Boyd
California Energy Commission

Norman L. Bryan
PG&E (retired)

David Burwell
BBG Group

Tom Eizember
Exxon Mobil

Robert Epstein
Environmental Entrepreneurs

Genevieve Giuliano
University of Southern California

David L. Greene
Oak Ridge National Laboratory

Larry F. Greene
Sacramento Metropolitan AQMD

David H. Hosley
Great Valley Center

Paul Howard
General Hydrogen

Wendy M. James
The Better World Group

Larry R. Johnson
Argonne National Laboratory

Kevin Knobloch
Union of Concerned Scientists

Chung S. Liu
South Coast AQMD

Alan C. Lloyd
Former CalEPA Secretary

Stephen C. Lockwood
Parsons Brinckerhoff

Hani S. Mahmassani
University of Maryland

Fred L. Mannering
Purdue University

Alexandra Morehouse
CA State Automobile Association

Larry Orcutt
California Dept. of Transportation

Neil C. Otto
Ballard Automotive (retired)

Robert F. Sawyer
CA Air Resources Board (former chair)

Joseph L. Schofer
Northwestern University

Jananne Sharpless
Former ARB Chair and CEC

Minoru Shinohara
Nissan Motor Company

Graeme Sweeney
Shell International Renewables

Andreas Truckenbrodt
DaimlerChrysler

Hiroyuki Watanabe
Toyota Motor Corporation

Brad Whitcomb
PG&E

Carol L. Whiteside
Great Valley Center

ITS UCDAVIS

Graduate Education

(with 2008-2009 numbers)

- Master's and Ph.D.
- Transportation Technology and Policy ***(44 students)*** (interdisciplinary and hosted by ITS-Davis)
  - Technology Track
  - Planning and Policy Track
- Traditional Academic Discipline ***(53 students)***
  - Engineering ***(29 Civil and 16 Mechanical Engineering)***
  - Social Sciences
  - Environmental Sciences
  - Management
- 15-20 grads/yr (50% gov't; rest to industry and academia)

Public Outreach is Central

PHEV Research Center Launch (2007)

- Major international conferences
- Specialized workshops
- 80+ papers/year; *ITS-Davis e-news* to 5000 quarterly
- Testimony to U.S. Congress and CA Legislature
- Technology demonstration and education

Gov. Schwarzenegger signs Hydrogen Highway Executive Order at UC Davis (2004)

Federal and State testimony

Building a Policy Agenda For GHG Reduction

- ITS-Davis hosted 11th biennial conference on **transportation energy and environmental policy** at Asilomar (Aug. 21–24, 2007, next July 28–31, 2009)
- Over 250 participants, including many senior California and federal agency staff
- Goal: Address climate change challenges and questions facing policymakers

Environmental Impacts, Air Quality & Energy

- Greenhouse gas emissions reduction strategies
- Impacts of alternative fuels
- VMT reduction and land use
- Air quality
- Lifecycle emissions and costs
- Energy use in China

Advanced Environmental Vehicle Research

- PHEVs, HEVs and EVs
- FCV Demonstrations
- Vehicle Modeling
- Markets and Marketing
- Refueling Infrastructure
- H2 Pathway Studies
- Fuel Cell APU
- Hydrogen/CNG Bus Technology Validation

Plug-in Hybrid Research Center Kick-off

Market Research

- Demand for telecommunications, PHEVs, fuel cell vehicles, fuel economy, car sharing, neighborhood cars, etc.
- AFV market research
  - Diesel cars in US; CNG in NZ and Canada; EVs and methanol in CA; fuel cell vehicles in US
- Unique Approaches and Tools
  - Household activity models, interactive consumer surveys, fleet purchasing behavior

Sustainable Transportation Energy Pathways

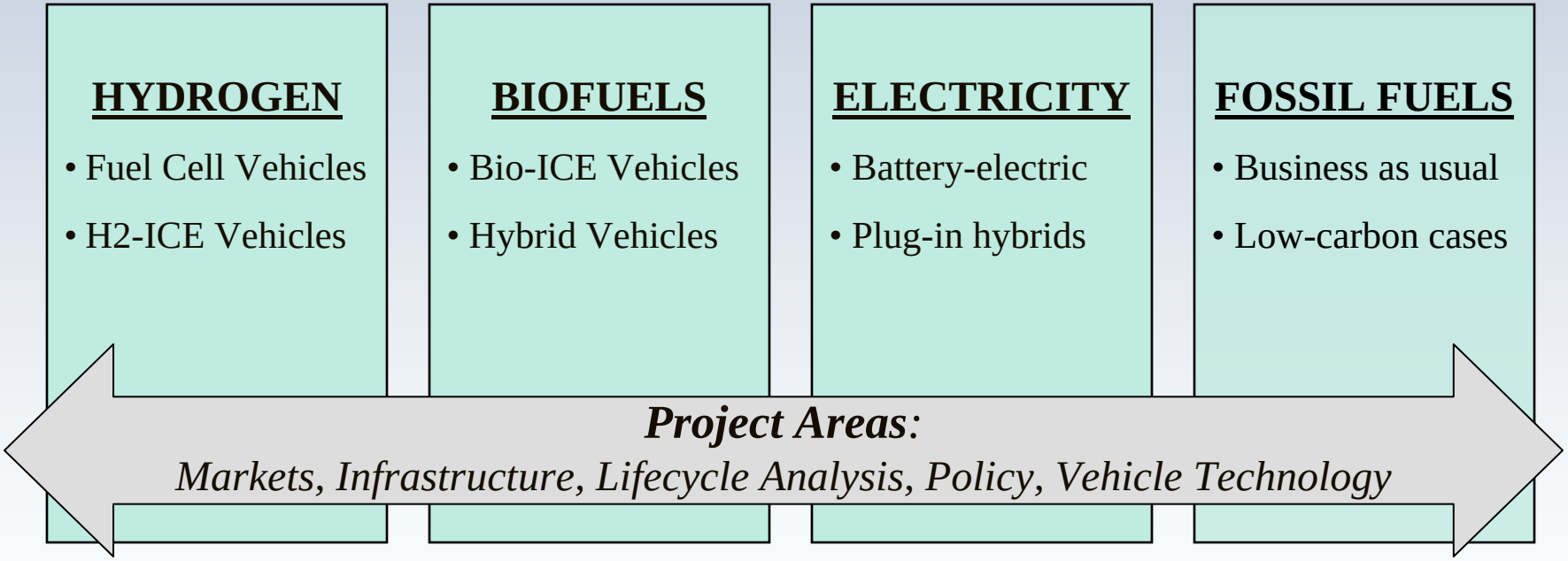
Biofuels

Hydrogen

Electric Drive

STEPS
Research Scope: Cross Comparisons

Three alternative “energy pathways” have been identified



The fourth “pathway” represents the evolving fossil fuel energy infrastructure

Addressing Transportation Energy Challenges

Climate change, Air quality, Energy security, Peak oil

Transportation Efficiency

- Vehicle fuel economy
- Congestion relief
- Road design
- Intelligent Transportation Systems (ITS)

Alternative Fuels & Vehicle Technology

- Hydrogen
- Biofuels
- Electric drive vehicles
- Advanced ICE engines
- Low-carbon liquid fuels

Reduced Vehicle Miles Traveled (VMT)

- Carpooling
- Mass transit
- Urban design

STEPS Focus

UCDAVIS ITS

STEPS Sponsors

UCDAVIS

PLUG-IN HYBRID ELECTRIC VEHICLE RESEARCH CENTER

of the Institute of Transportation Studies

- **California Energy Commission Funded**
  - New Transportation Research Area (TRA) PIER group
  - $3 million over three years from California Energy Commission
  - $1.8 million for next two years from California Air Resource Board
- **Early Accomplishments**
  - PHEV Research Roadmap development is ongoing with input from stakeholders and advisory council.
  - New-car buyer consumer research is underway. On-line survey is completed, in home placement is on-going.
  - Consumer, battery, and vehicle architecture research reports published.

Corporate Affiliates

- Patron Level
  - ExxonMobil
  - Nissan Technical Center North America
  - Shell
  - Toyota Motor Sales
- Basic Level
  - Aramco Services Company
  - Chevron Products Company
  - Mitsui PowerSystems
  - Nippon Oil
  - Pacific Gas and Electric
  - Fuji Heavy Industry

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PLUG-IN HYBRID ELECTRIC VEHICLE RESEARCH CENTER

pier
PUBLIC INTEREST ENERGY RESEARCH
"Research Powers the Future"

The PHEV Research Center

Prepared by: Dr. Tom Turrentine and Dahlia Garas

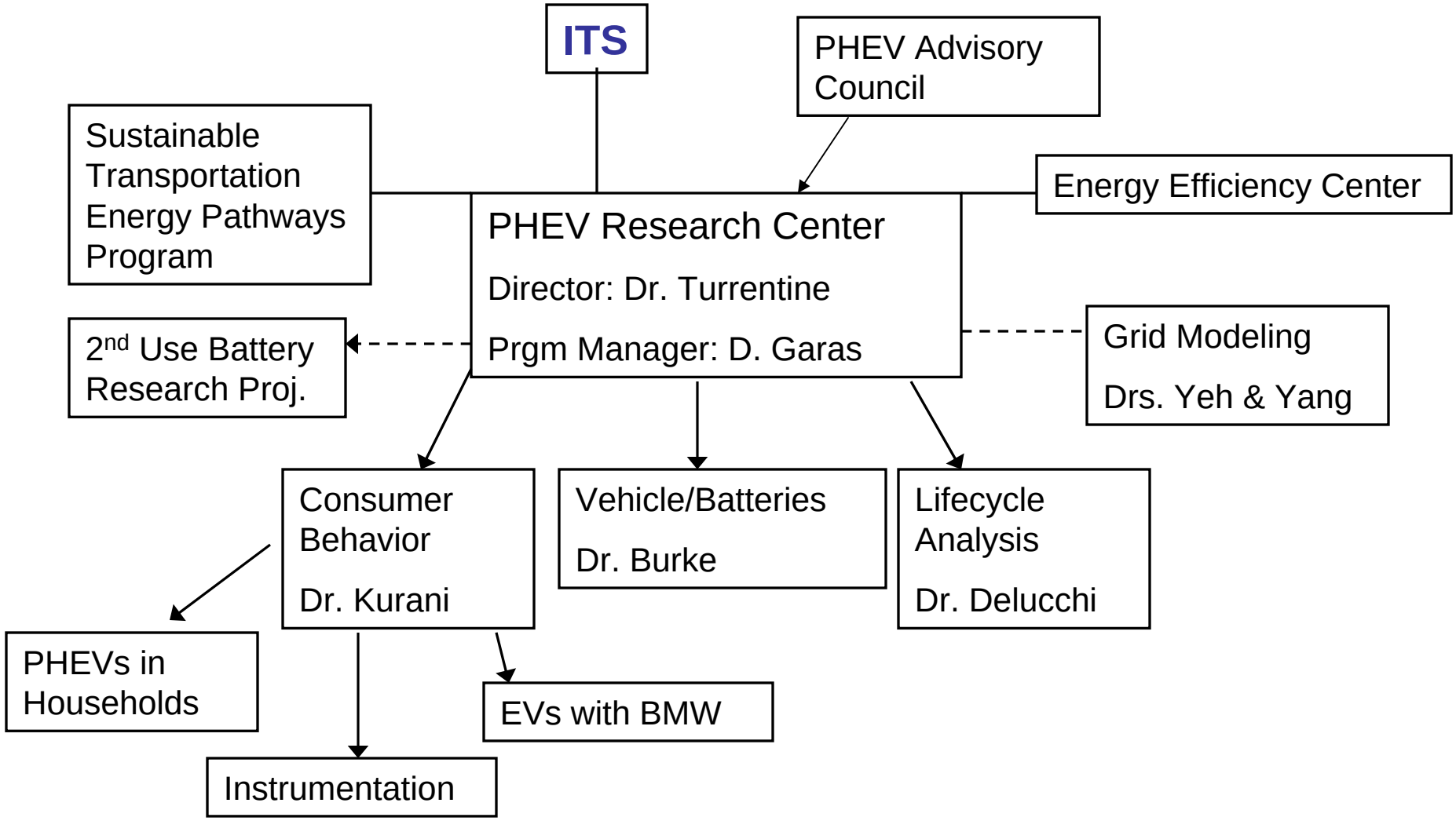
The PHEV Research Center

- Funded by the California Energy Commission in early 2007
  - New Transportation Research Area (TRA) PIER group
  - $3 million over three years
- $1.8 million for next two years from California Air Resource Board

PHEV Research Center Advisory Council

- Council Chair Jim Boyd, CEC
- Ed Wall, DOE
- Bill Boyce, SMUD
- Mark Duvall, EPRI
- Chung Liu, SCAQMD
- Jill Egbert, PG&E
- Joel Pointon, SDG&E
- Ed Kjaer, SCE
- Christian Mohrdieck, Daimler AG
- Nancy Gioia, Ford Motor Company
- Toshio Hirota, Nissan
- GM

PHEV Center Affiliations



Introduction to PHEVs

Architecture Vs. Attributes

Series – two motors, one engine, energy flows from engine through motor to wheels

Parallel – one motor, one engine, energy can flow from both in parallel to the wheels

Power-Split – two motors, one engine, combines elements of parallel and series through complex gear system

Chevrolet Volt

All-electric range

Plug-in capability

Li-ion batteries

110 V Charging

Increased fuel economy

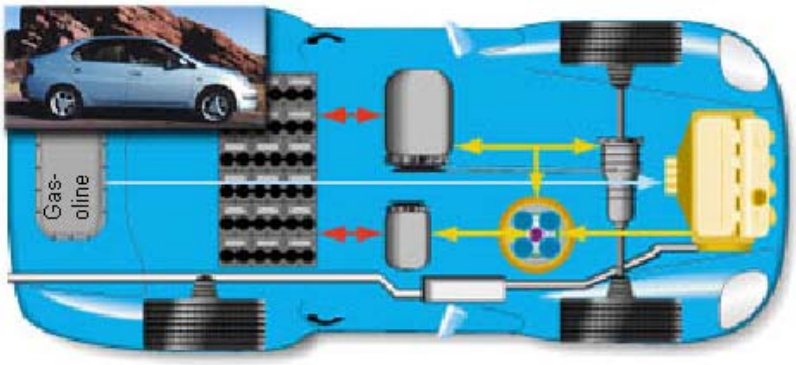


Image from Advisor program

Where to PHEVs fit?

Internal Combustion Engines (ICEs)

Hybrid Electric Vehicles (HEVs)

Lite → Mild → Full

Toyota Prius HEV / Honda Civic HEV

Plug in Hybrid Vehicles (PHEVs)

PHEV 5 → 60 Miles
Blended → AER

Prius Plus 20 PHEV
GM Volt 40 PHEV

Electric Vehicles (EVs)

50+ mi.

Tesla EV

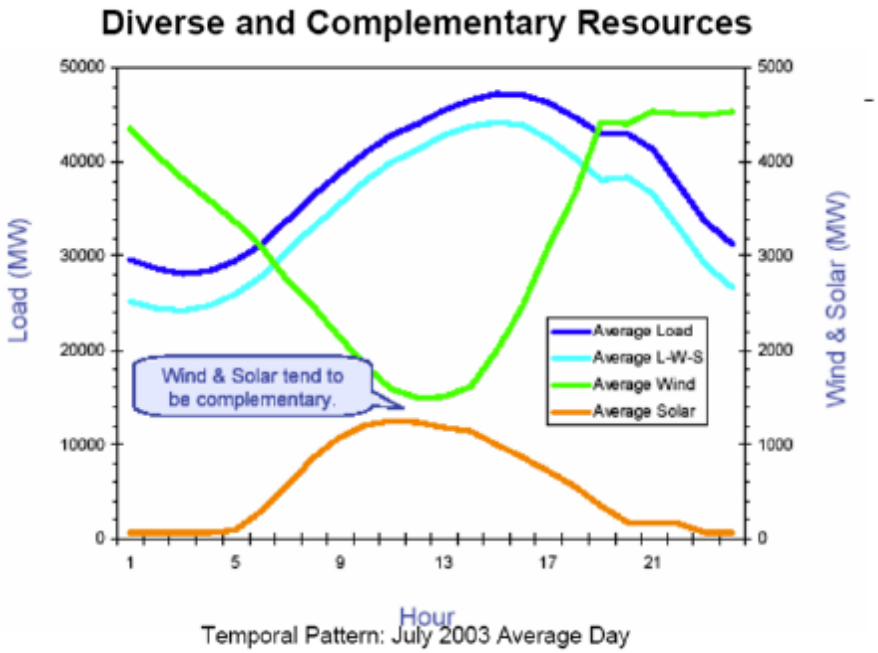
Gasoline/Diesel Dependent

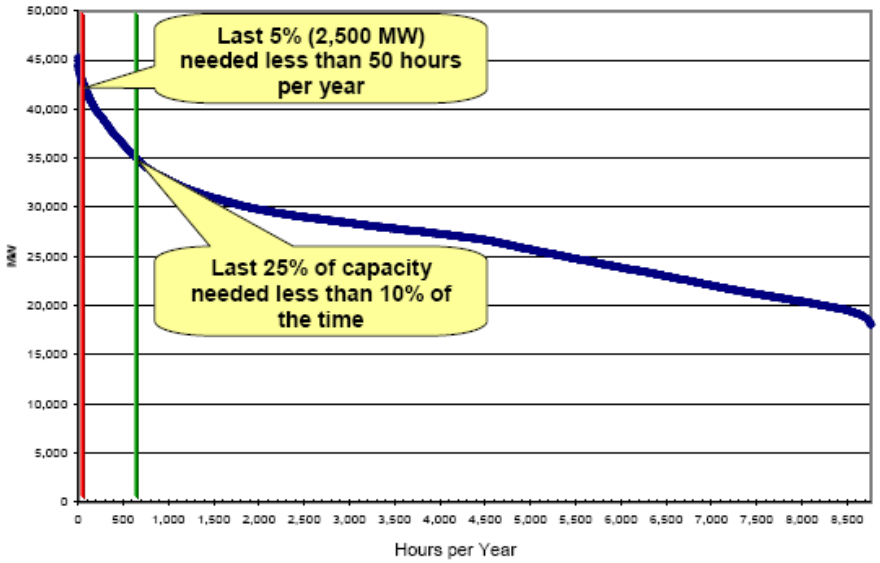
Electric Grid Dependent

Major Research Areas

1. Batteries
2. Vehicle architecture and control systems
3. Environmental benefits and lifetime costs
4. Consumer demand and use patterns
5. Infrastructure impacts
6. Codes and Standards

PHEVs and the Grid





1. Off-peak times (~ 8pm to 8am) have plenty of power available
2. 90% of the year we are using less than 75% of our generating capacity

Therefore, the grid has plenty of available power to charge PHEVs, off-peak.

1: Source PG&E from EPRI presentation at SAE HV Symposium, 2008 2: Source CalISO from EPRI presentation at SAE HV Symposium, 2008

PHEV Research Questions

- PHEV potential to address long-term energy & climate change challenges
- Tradeoffs of various PHEV architectures on cost, performance, environmental benefits, & energy impacts
- Understand consumer response to and use of PHEVs
- Impacts of PHEV use on the electric utility industry
- Identify policies & strategies that will be most effective in accelerating PHEV commercialization while maximizing the benefits to stakeholders.
- How to certify PHEVs for emissions
- Identify information automakers need or want before producing PHEVs

Vehicle Technology and Battery Evaluation

- Drs. Andrew Burke & Andrew Frank
- Expand existing vehicle modeling tools to fully incorporate PHEV powertrain, energy storage, & operating controls options.
- Evaluate performance differences across a varying range of technology combinations (battery pack size, electric drive size, charging voltage).
- Additional work on Li-ion battery testing in partnership with EPRI and SCE.

Energy, Environment and Cost Modeling

- Drs. Mark Delucchi, Marshall Miller
- Analysis of lifecycle environmental impacts & lifetime social cost
  - Expand the ITS-Davis Lifecycle Emissions Model (LEM) & Advanced Vehicle Cost & Energy-use Model (AVCEM) to fully incorporate PHEV technologies, operating characteristics, & electricity usage impacts
  - Estimate emissions of urban air pollutants & greenhouse gases, impacts on energy resources, & private & social lifetime costs

Consumer Behavior Studies

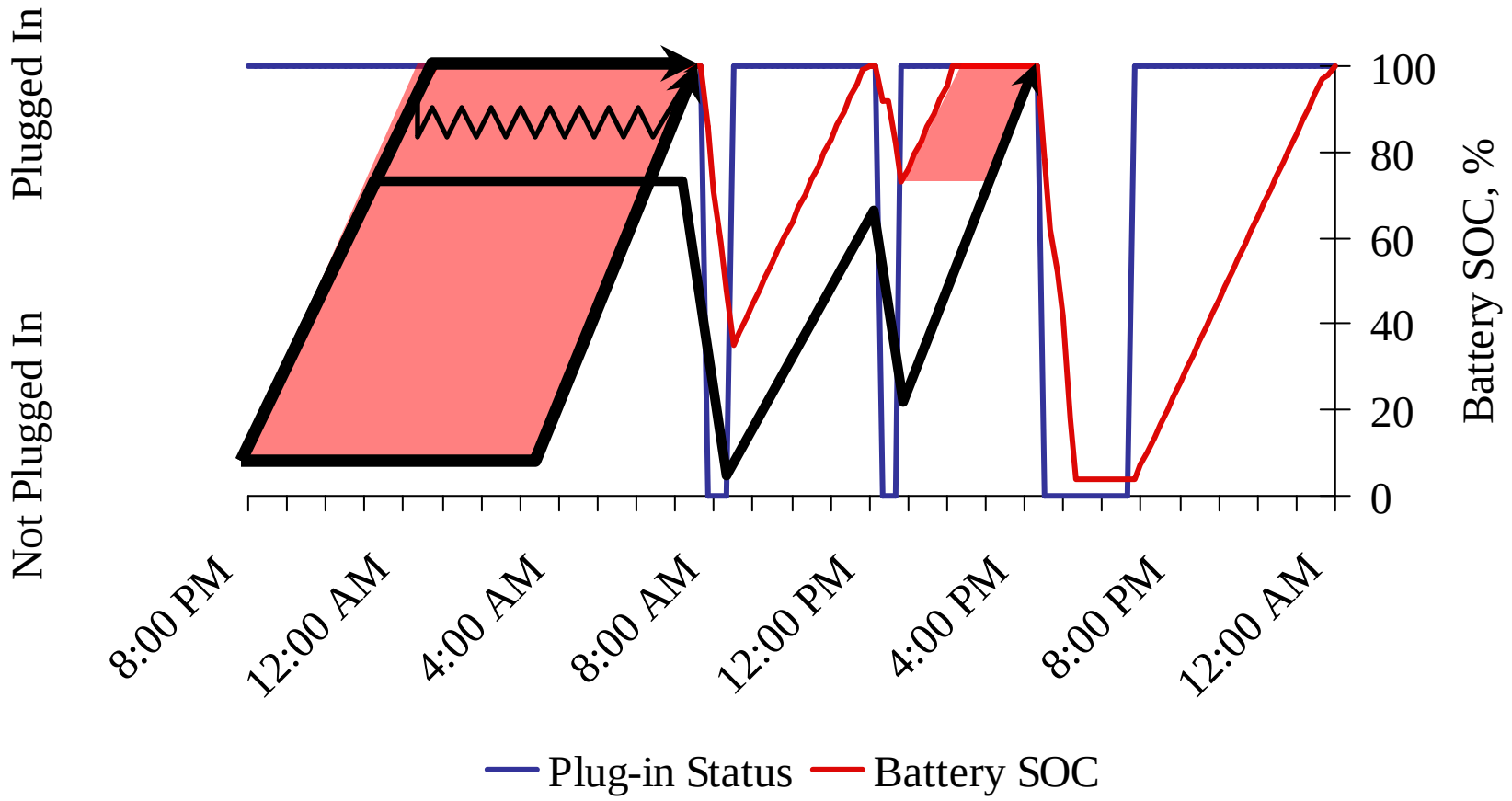
- Dr. Ken Kurani
- First Stage is a large internet-based survey on consumer knowledge and priorities of hybrids.
- Second stage is placing 10-20 converted PHEVs in 100 households or businesses in California
  - 6-8 weeks each
  - 2-3 year study period (2007-2010)
  - GPS data on use patterns using data acquisition
  - Detailed interview data on household

- Final stage is using advanced energy feedback displays with real-time cost, total fuel economy, emissions etc.

PHEV Innovator Study, (UCD,2007)

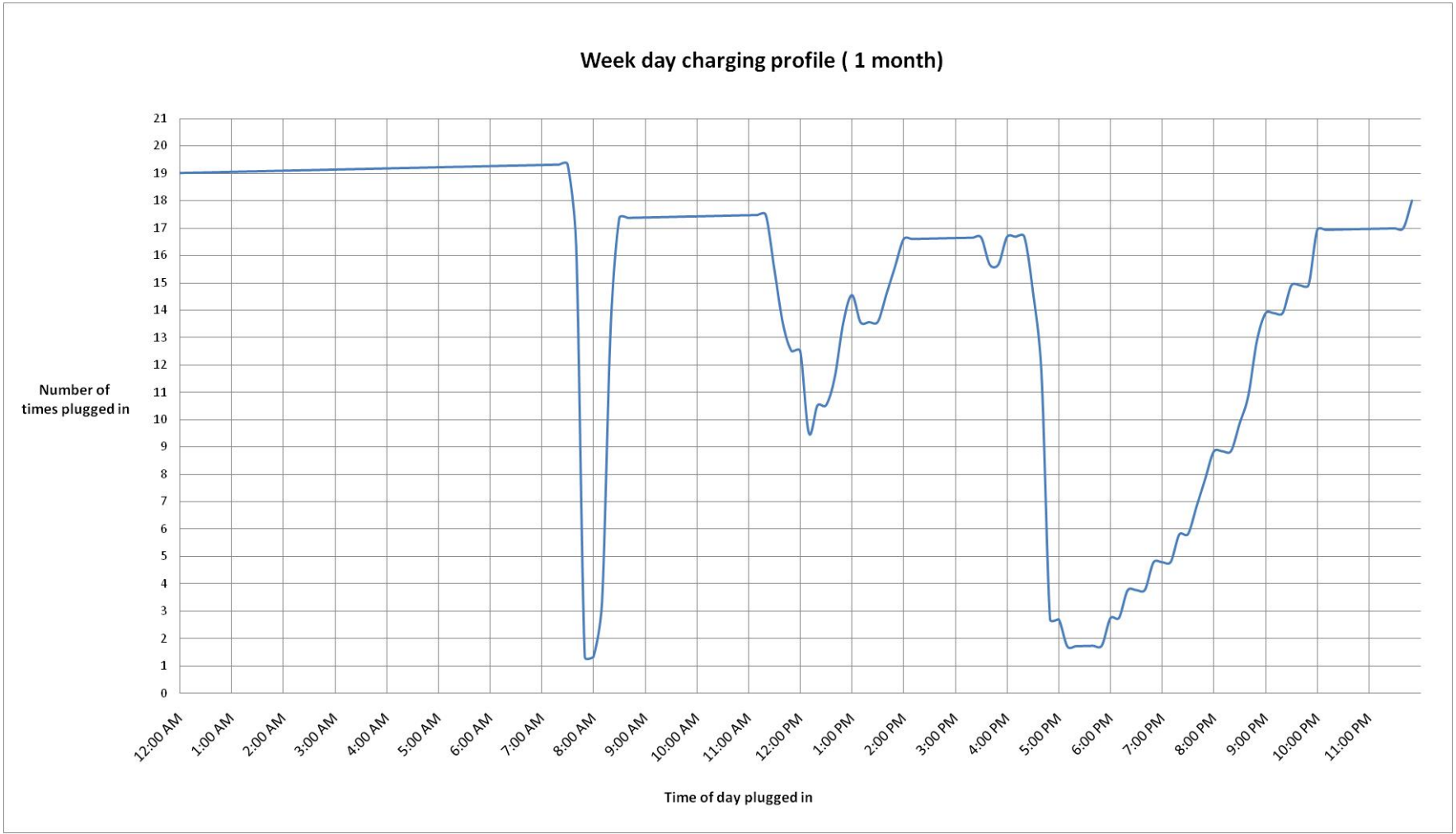
- **Drivers of Prius-Based PHEV Conversions**
  - **Individual Owners as well as Employees from Utilities, Government Agencies, and Nonprofits**
- **Strong Preference for Longer All-Electric Range and Greater All-Electric Performance**
  - **Many Participants Had Previous EV Experience**
- **Important Meaning in 100 MPG (Blended-Mode)**
  - **Key Role of Fuel Economy Instrumentation**
- **Strong Inclination to Plug-in Whenever Possible**
  - **Economic Calculations Uncommon**
  - **Recharging Hard for Vehicles Lacking “Home Base”**
- **Some Frustration with Automakers**
  - **PHEV Advocacy Can Get Ahead of Technology**

Vehicle Plug-in Status and Battery SOC: One household, 28 (weekday) hours



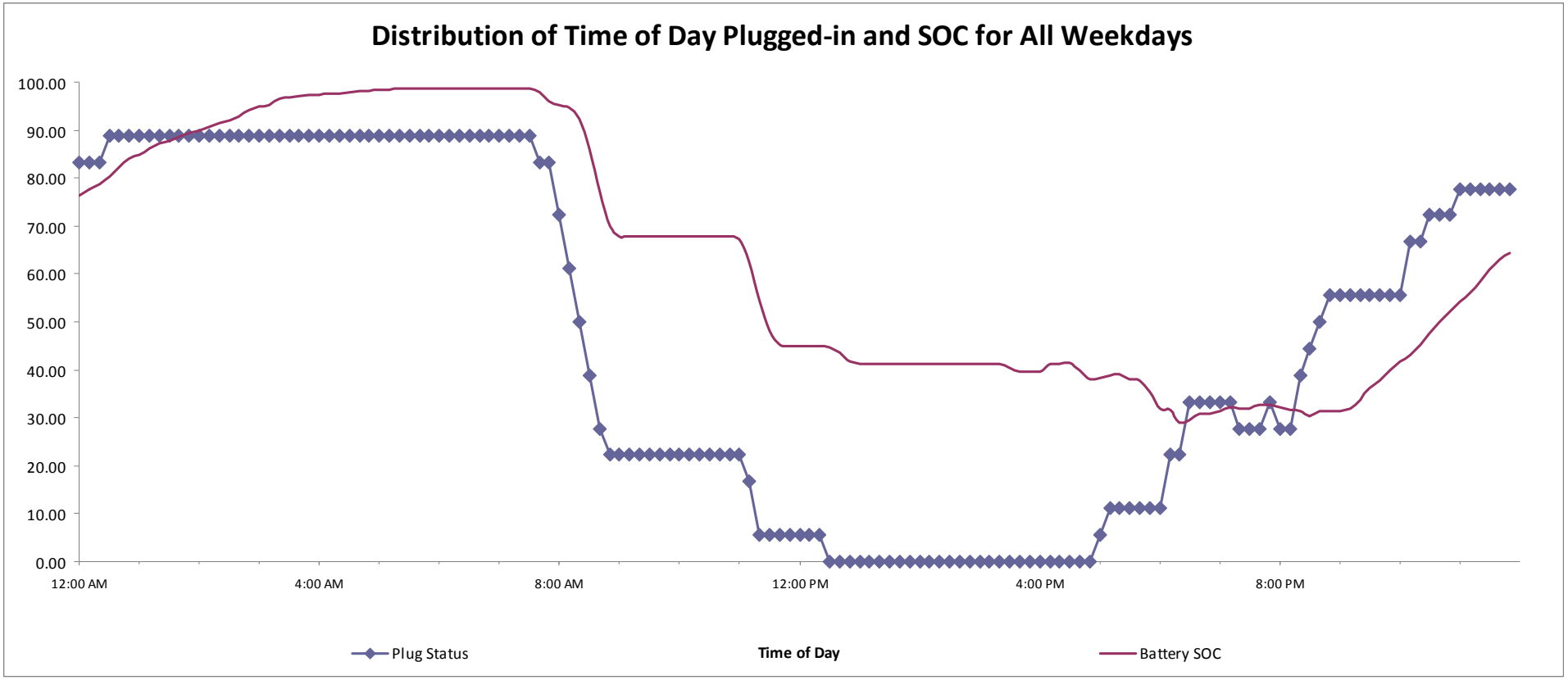
Household 1: one month of data

Aggregate of one households weekdays



Household 2: One month of data

Aggregate of one households weekdays



PHEVs and Consumers

Early Household study results – 28 households

- Thirteen 2nd generation (crash tested) conversion PHEVs in the UCD fleet.
- Study results show that 55% of trips and 37% of miles are in Charge Depleting mode.

Early Fuel Economy results

- Average charge depleting fuel economy of 70 mpg.
- Average charge sustaining (traditional hybrid operation) fuel economy of 43 mpg.
- 28-household average overall fuel economy of 50 mpg.

New Research Initiatives

1. BMW MiniE Consumer Study
2. 2nd Life of Lithium Batteries
3. Phase 2: PHEV Demo
4. User Interfaces (PHEV Center and EEC)

BMW MiniE

- February 2009-June 2010
- BMW 500 “conversions” of Mini to 154 mile range EV with 35 kWh lithium battery (takes up back seat) 1 year, $850 month lease
- UC Davis is lead University to work with BMW. (cooperating with team at Chemnitz University (Saxony) 50 MiniEs in Berlin
- 18 month project; interviews and surveys with a subset of 50 households (25 in New York, 25 in Los Angeles, $239,000

2nd Life Battery Study

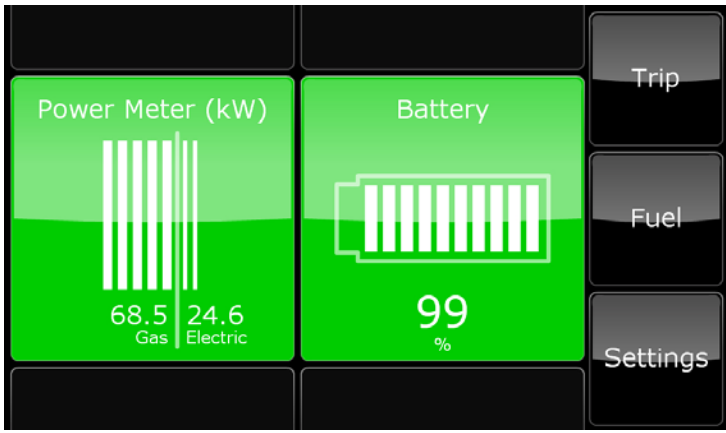
- PHEV center issuing RFP, with $700,000 CEC PIER money and $700,000 from DOE. PHEV center will manage project -$50,000.
- Lithium batteries are expensive- $1000 kWh for PHEV batteries.
- Batteries are retired from EVs/ PHEVs at 80% of capacity.
- Explore potential “2nd” application
  - Accelerated aging of batteries to “5 years”
  - Place batteries in 2nd life for testing-housholds.
  - Characterize performance and charge cycles

Phase 2: PHEV Demo

- July 2009-Dec 2010
- Continue placements of 13 PHEVs
- Add 2 new EVs
- Add “energy feedback instruments” (designed by ITS)
- Add “photovoltaic charging stations”
- Add “smart meters” (PGE)
- Funded through Fall 09

User Interface

- 3 year, Cross-sector study of consumer response to new energy feedback displays ($2 million)
- Thermostats
- Lighting controls
- Vehicles: PHEVs, EVs, HEVs:Real time cost per mile: Real-time CO2; Trip, daily and total average fuel economy



UCDAVIS

SUSTAINABLE TRANSPORTATION ENERGY PATHWAYS

An Institute of Transportation Studies Program

Program Overview

Peter Dempster, Program Manager

Presentation for the Austrian Business Delegation

May 15, 2009

Presentation Outline

- Program Overview
- Research Highlights
- *Looking into the Future for STEPS*

Addressing Transportation Energy Challenges

Climate change, Air quality, Energy security

Reduced Vehicle Miles Traveled (VMT)

- Carpooling
- Mass transit
- Urban design
- Intelligent Transportation Systems (ITS)

Vehicle Technology

- Advanced conventional vehicles (ICE)
- Plug-in hybrid electric
- Battery electric
- Fuel cell electric

Fuel Alternatives

- Hydrogen
- Biofuels
- Electricity
- Low-carbon liquid fuels (coal / NG with sequestration)

A comprehensive energy strategy should have a "portfolio" approach with multiple solutions

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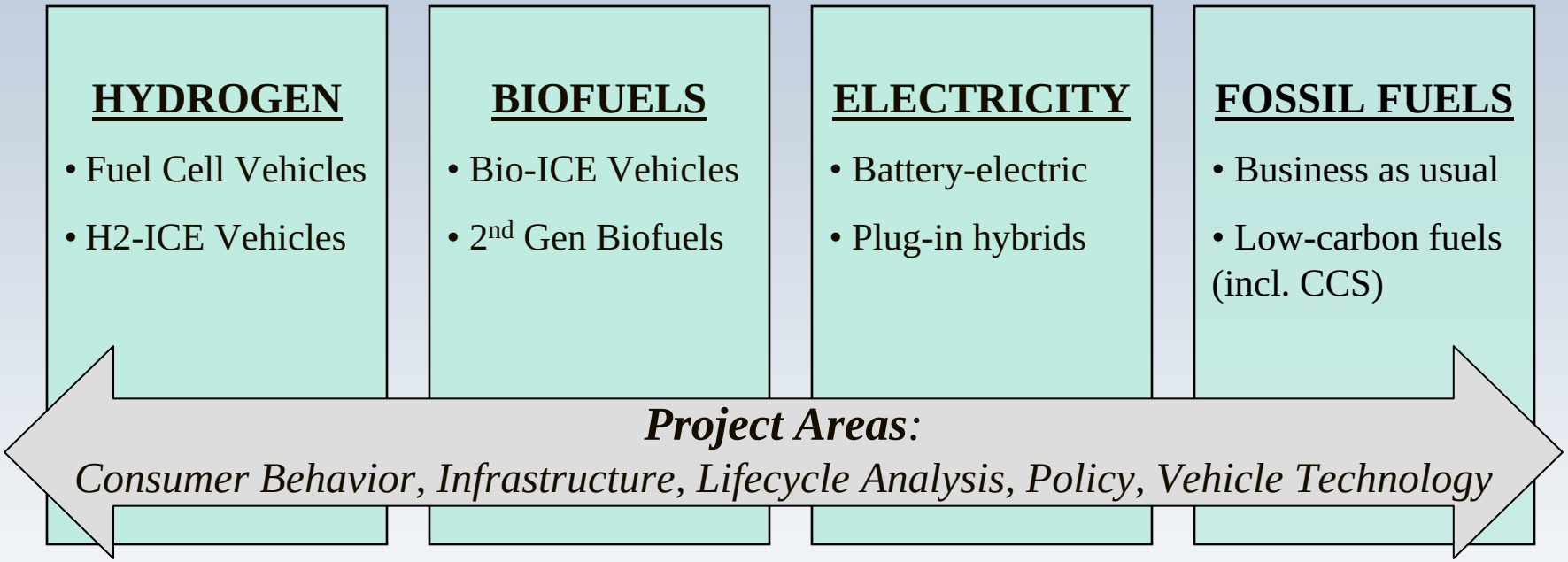
STEPS Program Scope



GOAL:

Conduct robust comparisons of different fuel / vehicle pathways

RESEARCH *EDUCATION* *OUTREACH*

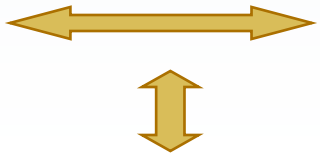
Research Leadership

Joan Ogden and Dan Sperling, Directors

Tracks / Threads	**Hydrogen, FCV** Joan Ogden	**Biofuels** Bryan Jenkins	**Electric Drive** Tom Turrentine	**Fossil Fuels** Cynthia Lin
Demand and Behavior Ken Kurani				
Infrastructure Modeling Chris Yang, Yueyue Fan				
Energy, Environ., & Cost Analyses Mark Delucchi				
Policy and Business Strategy Chris Knittel				
Vehicle Evaluation Andy Burke				
Scenarios Sonia Yeh				

Threads: "Cross-Comparison" Focus

Tracks: "Interdisciplinary" Focus



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Program Numbers

- Sponsors: 22 (16 industry, 6 gov)
- Faculty & researchers: 15
- Graduate Students: 25 (22 PhD, 3 MS)
- Collaborating departments:

  Environmental Science & Policy, Civil Engineering, Biological & Agricultural Engineering, Mechanical and Aeronautical Engineering, Economics, Agriculture & Resource Economics, Plant Sciences

Publications and Awards (2007 & 2008)

- **Publications: 80 +** (full list at www.steps.its.ucdavis.edu)
- **Awards:**
  - 2008 Barry McNutt Award for Best Paper on Energy, Transportation Research Board (Knittel, Hughes, Sperling)
  - 2007 Barry McNutt Award for Best Paper on Energy, Transportation Research Board (Nicholas, Ogden)
  - 2008 University of California, Davis Chancellor's Fellow Award (Knittel)
  - 2007 Best Paper from the Scientific Committee of the 2nd World Congress of Young Scientists on Hydrogen Energy Systems (Z.Lin)
  - 2007 ITS-Davis Outstanding Master's Thesis Award (McCollum)
  - 2007 University of California, Davis Distinguished Scholarly Public Service Award (Ogden)
  - 2007 Charley V. Wootan National Student Award for best Master's Thesis in Transportation Policy and Planning (Parker)
  - Portion of the Nobel Peace Prize for his contributions to the United Nations' Fourth IPCC Report (Sperling)
  - 2007 UC Davis Sustainable Transportation Center's "Outstanding Student of the Year." (Weinert)

STEPS Research Informs the Policy Process

- Prof. Dan Sperling leads UC Davis team on UC Low Carbon Fuel Standard reports. 7 STEPS researchers contribute to reports.
- Prof. Dan Sperling - NRC Committee on Energy
- Prof. Dan Sperling - American Physical Society Committee on Energy Efficiency
- Prof. Bryan Jenkins, Nathan Parker Western Governor's Association report on biofuels
- Prof. Joan Ogden – CARB Economic and Technical advisory panel for implementation of AB-32
- Prof. Joan Ogden - NRC committee for H2 & Fuel Cells, developed analysis for report with Dr. Chris Yang, Dr. Marc Melaina
- Prof. Joan Ogden – US Department of Energy, Hydrogen Technical Advisory Committee
- Prof. Cynthia Lin appointed to CA state economic advisory group (2007 -)
- Dr. Sonia Yeh, Dr. Nic Lutsey, modeling for CA LCFS implementation
- Anthony Eggert – Energy advisor to CARB; involved with AB-32 scoping plan
- Numerous interviews with the media (NPR, NY Times, LA Times, etc.)
- Numerous invited talks at national meetings and policy forums

UCDAVIS ITS

STEPS Program Events (2009)

- Policymaker outreach
  - Washington, DC, January 2009
- Sponsors workshop
  - Davis, CA, March 2009
- STEPS Advisory Board Meeting
  - Asilomar, CA, Summer 2009
- Sponsors Research Symposium
  - Davis, CA, Fall 2009

Program Activities & Sponsor Benefits

- Research Reports
- Quarterly Newsletter
- Sponsors Website
- Technical Workshops
- Public Process Activities
- STEPS Advisory Committee
- Sponsor Advisors and Internships
- **New** biennial program report
  - Expected release in Spring 2009
- **New** White paper series

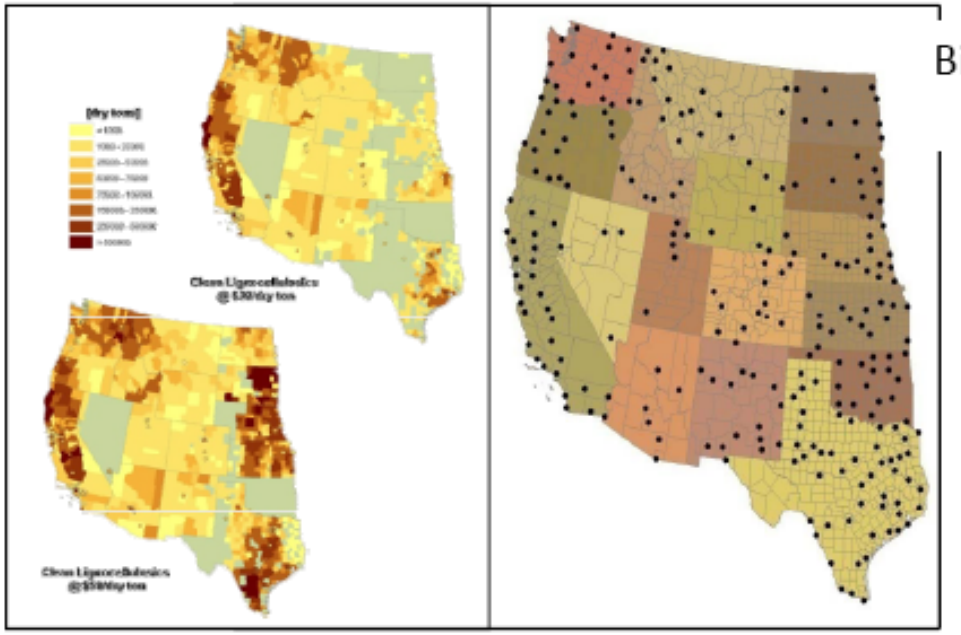
Research Highlights

Evolving STEPS Research Goals

- Single pathway analyses =>
- Robust comparison of fuel pathways =>
- Integrative scenarios for future vehicles and fuels
- Case studies that inform carbon and alternative fuel policies in CA and the US

Assessing Biofuels Potential in the Western U.S.

Feedstock GIS mapping



Biorefinery location optimization

STEPS Engineering/economic models coupled with GIS spatial data and math. optimization techniques =>
low cost bio-fuel supply strategies

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Potential for Plug-In Hybrid Vehicles (J. Axsen, K. Kurani, A. Burke)

The role of plug-in hybrid electric vehicles (PHEVs) in meeting future energy and emissions goals depends not only on technology, but also on drivers' travel and recharging behaviors.

- STEPS researchers surveyed potential PHEV users, finding that at least half of the respondents live in homes suitable for at-home recharging.
- The appeal of increased fuel economy with PHEVs ranked higher than a large all-electric range or speed. This result may help to inform decision-makers implying that smaller battery systems may be appropriate.

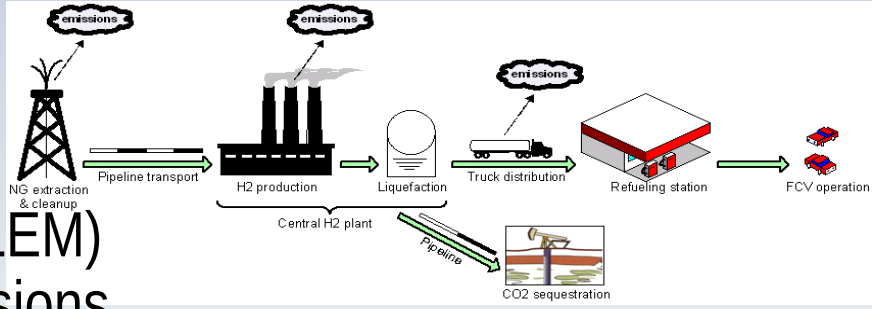
STEPS researchers assessed the status of Advanced Battery technologies for Plug-In Hybrid applications

Research Highlights (continued)

Cross Comparative Projects

Energy, Environmental, Social Cost Analyses

What are the Emissions, Energy Use, Land and Water Use, and Social Costs of Fuel/vehicle pathways?



Projects:

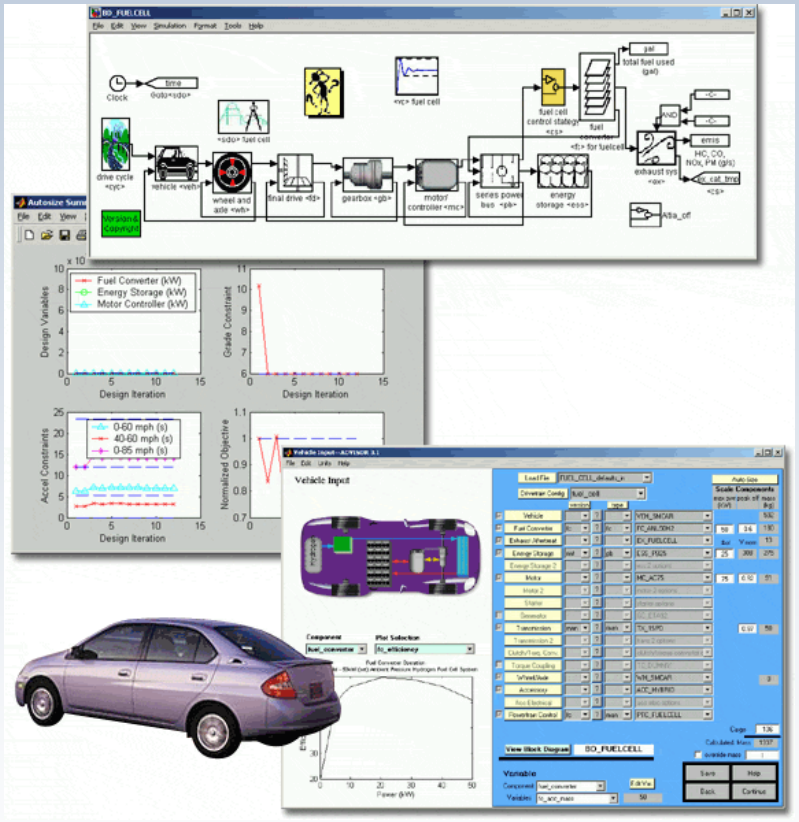
- UC Davis Lifecycle Emissions Model (LEM) and Alternative Vehicle Cost and Emissions Model (AVCEM); Social Cost Analyses
- Lifecycle Analysis of Biofuels including land use effects.
- Assess Water Use Impacts of Alternative Fuels
- Compare regional air pollution impacts for alt fuel pathways

Cross Comparative Projects

Vehicle Modeling

How do various types of vehicles compare? (Performance, cost, design)

- **Research Projects**
  - **Improve models of advanced vehicle performance and cost**
  - **Make self-consistent comparison of Gasoline ICEVs, Hybrids, plug-in hybrids, PEM fuel cell vehicles**



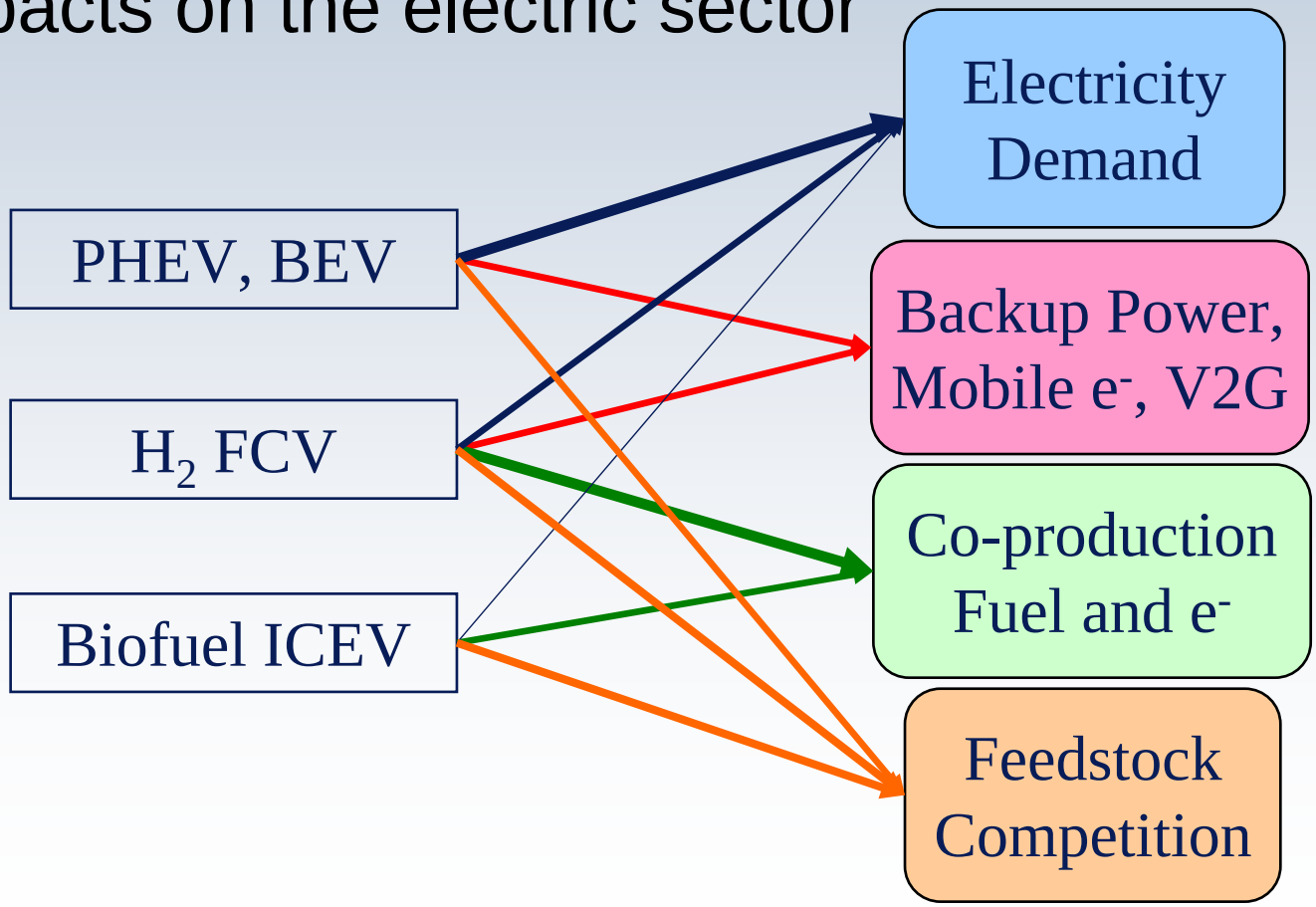
INTEGRATIVE SCENARIOS

- What are the limiting factors, timeframe for adoption of new vehicles and fuels?
  - What are viable near-term solutions?
  - How do we transition to long-term solutions?
  - Will solution-sets be different by world regions?
  - What policy levers are needed to move society in this direction?
- What are prospects for meeting long term goals for GHG reductions and energy supply?
- How long will a transition take? How much will it cost?
- What are the synergies between pathways?

Integrative Scenarios

Transportation and the Electric Sector

Advanced vehicles and fuels will have important impacts on the electric sector



Modeling the Impact of Advanced Vehicles on CA Grid

(R. McCarthy, C. Yang)

Added demand for PHEV-20 w/ nighttime charging *

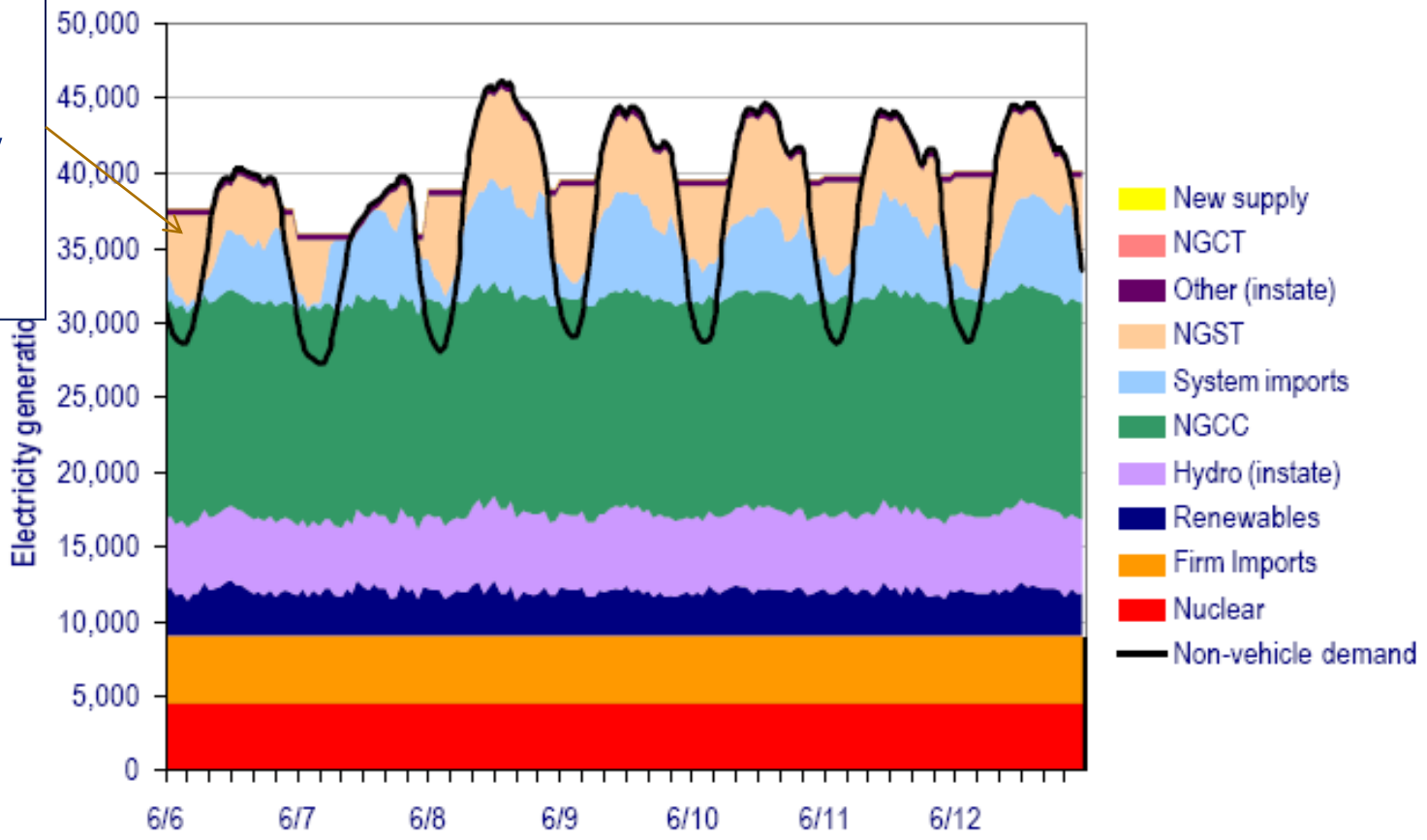


Figure 5: Dispatch model output for week of 6/6/07 (50% PHEV20s, load-leveling).

Marginal Generation for PHEV-20 charging mostly NG-Based

* PHEV-20 = Plug-in Hybrid w/20 mile all-electric range

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PHEV-20 has lower GHG emissions/mi than Gasoline hybrid, but slightly more than FCV w/ H2 from onsite natural gas reformer

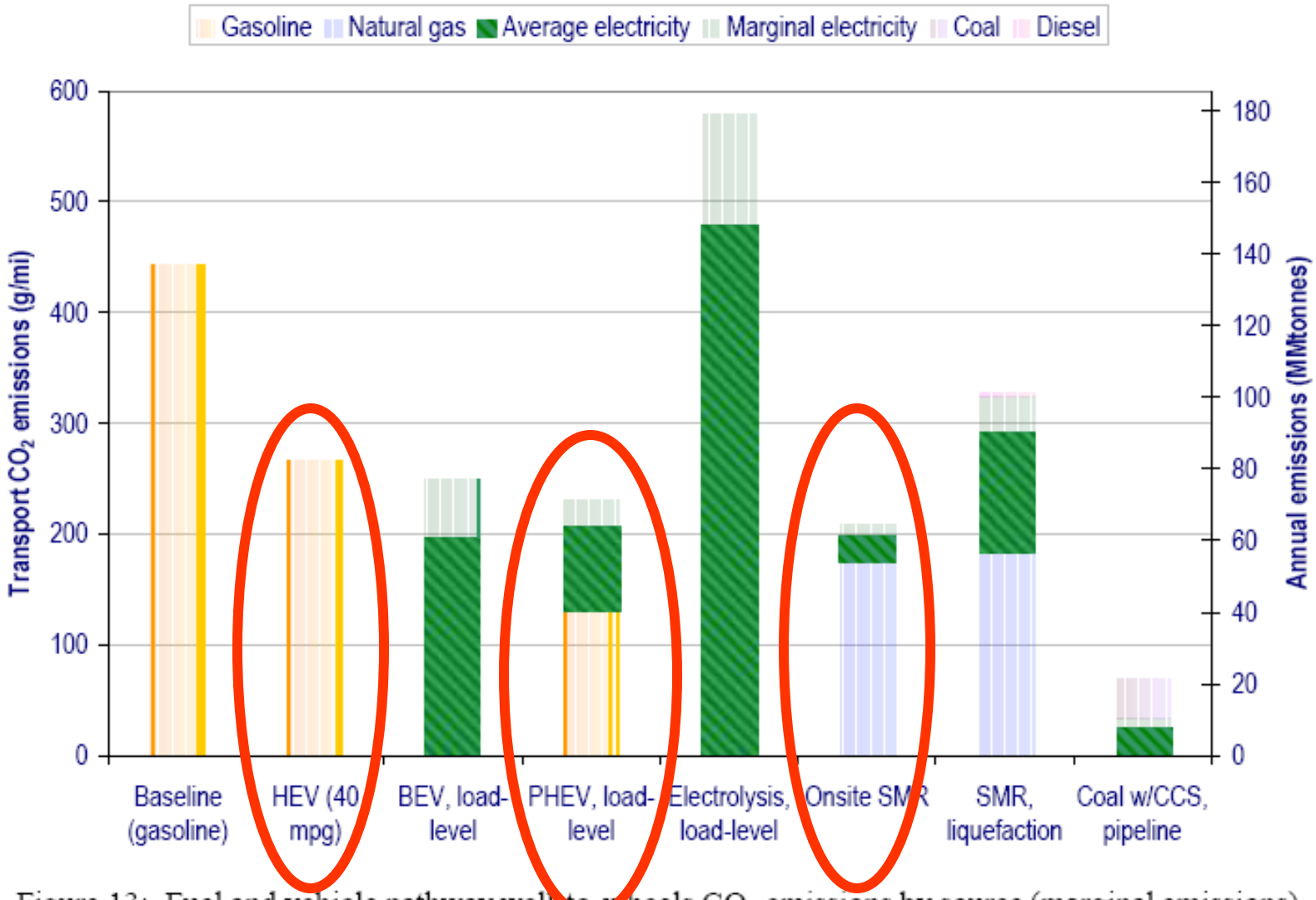

Figure 13: Fuel and vehicle pathway well-to-wheels CO_2 emissions by source (marginal emissions).

STEPS Scenario Modeling Projects

- MARKAL/TIMES model development for alternative fuel scenarios.
  - CA specific model as well as world regional case studies
- Low Carbon Fuel Standard (LCFS) projects
  - Multi-sector trading, blended fuel strategies, policy analysis
- 80 in 50 study
  - Options for reducing GHG emissions from California transportation sector by 80% by 2050.
  - Extend to US, and examine transition pathways
- Energy scenario simulation project
  - Develop a tool for group simulation, multi-stakeholder game-theory exercise
- Infrastructure Rollout Strategy Regional Studies

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An analysis of transportation options for meeting California's long-term greenhouse gas emissions reduction goals

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Emission Analysis Framework

$$CO_{2,Transport} \equiv \left(Population\right)\left(\frac{Transport}{Person}\right)\left(\frac{Energy}{Transport}\right)\left(\frac{Carbon}{Energy}\right)$$

$$P \times T \times E \times C$$

Population
California pop.

Transport intensity
(e.g., VMT/capita)

Energy Intensity
(e.g., MJ/mile)

Carbon Intensity
(e.g. gCO_2-eq/MJ)

- Decomposes emissions into major driving forces of interest
- Terms are treated independently
- Each transport sector option is characterized in terms of these components
  - Light duty, heavy duty, aviation, rail, marine, agriculture, off-road
- Develop emissions tool for calculating scenario emissions
- Develop scenarios of possible 2050 transport mixes

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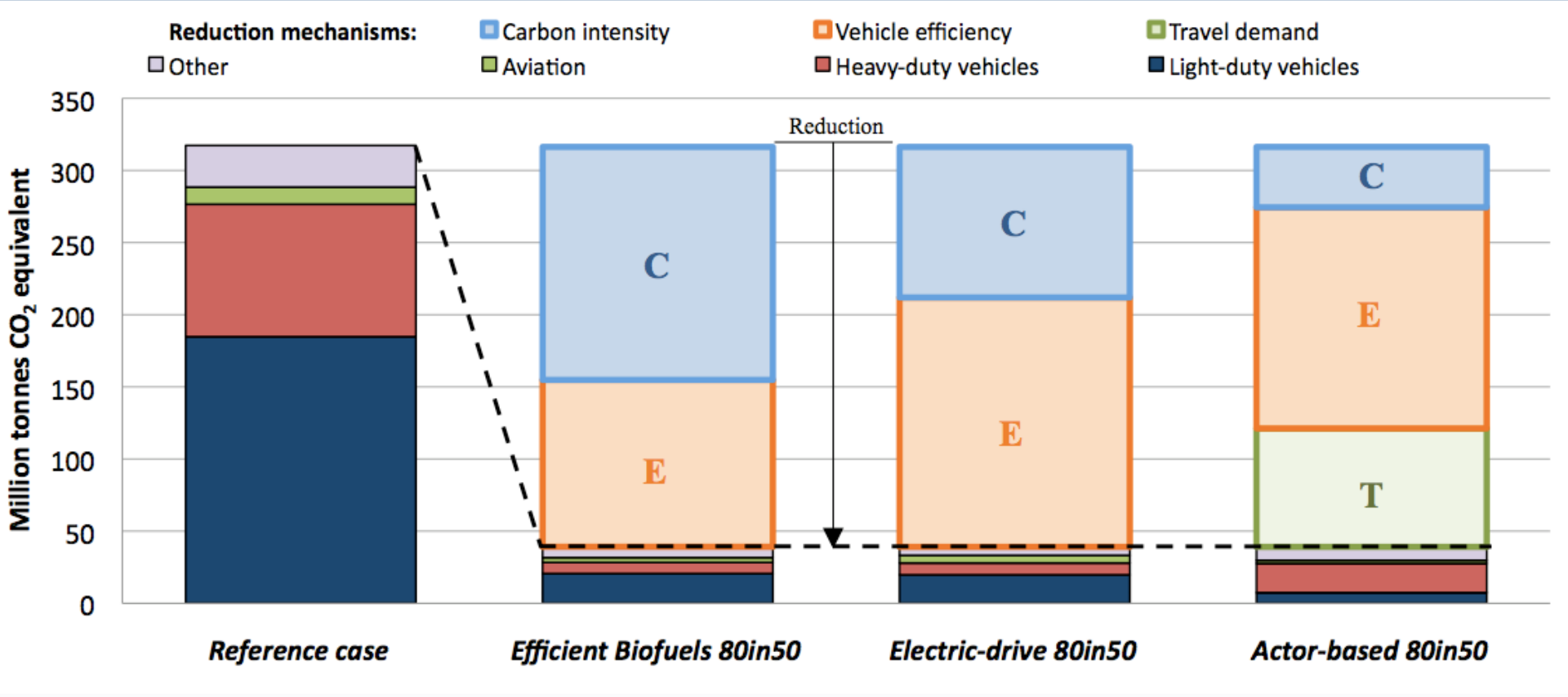
80in50 Scenarios

- ***Efficient Biofuels 80in50*** - Advanced technologies are developed for biofuel production. *Reference* travel demand. Low-carbon biofuels are the primary fuel in efficient vehicles (2x vehicle efficiency) across all sectors. Petroleum accounts for only 3% of fuel used.
- ***Electric-drive 80in50*** - Advanced technologies for electric drive vehicles and very low-carbon electricity and hydrogen are developed. *Reference* travel demand. Higher efficiency (3x) electric drive vehicles (EVs, PHEVs and FCVs) used in most sectors, except marine aviation and off-road where biofuels are used. Petroleum accounts for only 10% of fuel used.
- ***Actor-based 80in50*** - *High prices reduce travel demand and lead to smaller, high efficiency vehicles*. Reduced travel demand, very high efficiency vehicles, increased carpooling and use of transit. Fuels are not as decarbonized as in other scenarios. Biofuels used in aviation and marine. Petroleum still accounts for 35% of fuel used.

While no one mitigation strategy can single-handedly meet the target, the target can be met utilizing a combination of technological and behavioral strategies—a portfolio approach.



Future research directions

1) Better quantify transition timing and costs for various alternatives.
2) Better understand interactions between electricity and transportation sectors in future low carbon energy system.
3) Examine role of transportation in the energy system through economic modeling.
4) Regional factors are clearly important. Case study approach to model transitions.
5) Sustainability implies more than just adequate energy supply and low carbon. There are other important constraints: we have studies underway on water-energy and land-energy connections, and might also look at materials constraints on developing new low C energy systems.

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